

# INTERNATIONAL COOPERATION TREATY

PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner  
US Department of Commerce  
United States Patent and Trademark  
Office, PCT  
2011 South Clark Place Room  
CP2/5C24  
Arlington, VA 22202  
ETATS-UNIS D'AMERIQUE  
in its capacity as elected Office

<b>Date of mailing (day/month/year)</b> 30 May 2001 (30.05.01)	
<b>International application No.</b> PCT/GB00/03368	<b>Applicant's or agent's file reference</b> 4/W32338WO
<b>International filing date (day/month/year)</b> 01 September 2000 (01.09.00)	<b>Priority date (day/month/year)</b> 09 September 1999 (09.09.99)
<b>Applicant</b> SAUNDERS, Simon, Reza et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

24 March 2001 (24.03.01)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was  
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

<b>The International Bureau of WIPO</b> 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	<b>Authorized officer</b> Olivia TEFY Telephone No.: (41-22) 338.83.38
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Copy for the designated Office (DO/US)  
**PATENT COOPERATION TREATY**

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**COMMUNICATION IN CASES FOR WHICH  
NO OTHER FORM IS APPLICABLE**

From the INTERNATIONAL BUREAU

To:

MATHISEN, MACARA & CO.  
The Coach House  
6-8 Swakeleys Road  
Ickenham  
Uxbridge  
Middlesex UB10 8BZ  
ROYAUME-UNI

Date of mailing ( <i>day/month/year</i> ) 17 October 2000 (17.10.00)	
Applicant's or agent's file reference 4/W32338WO	<b>REPLY DUE</b> see paragraph 1 below
International application No. PCT/GB00/03368	International filing date ( <i>day/month/year</i> ) 01 September 2000 (01.09.00)
Applicant UNIVERSITY OF SURREY	

1. ☐ REPLY DUE within \_\_\_\_\_ months/days from the above date of mailing  
☐ NO REPLY DUE, however, see below  
☒ IMPORTANT COMMUNICATION  
☐ INFORMATION ONLY

2. COMMUNICATION:

Pursuant to the receipt of a Communication from the Patent Office (RO/GB), the International Bureau informs that the International Filing Date in the above-identified international application has been corrected to read : 01 September 2000 (01.09.00) instead of 04 September 2000 (04.09.00). Please correct all communications from the International Bureau to indicate the corrected international filing date.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer R. Raissi
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

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REC'D 28 DEC 2001

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 4/W32338WO	<b>FOR FURTHER ACTION</b>	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB00/03368	International filing date (day/month/year) 01/09/2000	Priority date (day/month/year) 09/09/1999
International Patent Classification (IPC) or national classification and IPC H01Q11/08		
Applicant UNIVERSITY OF SURREY et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.



2. This REPORT consists of a total of 5 sheets, including this cover sheet.

- ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand 24/03/2001	Date of completion of this report 21.12.2001
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Marot-Lassauzaie, J Telephone No. +49 89 2399 2671 

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# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/03368

## I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

### Description, pages:

1-18 as originally filed

### Claims, No.:

1-26 as originally filed

### Drawings, sheets:

1/6-6/6 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
  - ☐ the language of publication of the international application (under Rule 48.3(b)).
  - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).
3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:
- ☐ contained in the international application in written form.
  - ☐ filed together with the international application in computer readable form.
  - ☐ furnished subsequently to this Authority in written form.
  - ☐ furnished subsequently to this Authority in computer readable form.
  - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
  - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.
4. The amendments have resulted in the cancellation of:
- ☐ the description, pages:
  - ☐ the claims, Nos.:

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# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/03368

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

### 1. Statement

Novelty (N)	Yes: Claims 1-25
	No: Claims 26

Inventive step (IS)	Yes: Claims
	No: Claims 1-26

Industrial applicability (IA)	Yes: Claims 1-26
	No: Claims

2. Citations and explanations  
**see separate sheet**

## VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:  
**see separate sheet**

## VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:  
**see separate sheet**

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**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

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International application No. PCT/GB00/03368

**Re Item V**

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

D1: WO 99/41803

D2: US-A-4 554 554

2. The application is obviously directed to a system similar to the one of D1 with the added characteristic that some of the filament are in a fixed phase relationship, i.e. that they have no phase control between them.
3. Considering that the invention in D1 was to add the phase control means in the first place, the examiner cannot see any inventive step in partially removing them.
4. It should also be pointed out that adding any conductor to the antenna of D1 without connecting it through a phase shifter will lead to the antenna of claim 1. There are various common reasons that would require adding a conductor to the antenna of D1 in the course of normal manufacturing practice, such that:
  - shaping the radiating wires differently, e.g. for increasing bandwidth
  - adding stubs, coils or other widely used matching devices to the wires
  - manufacturing the wires in segments attached together.
5. Document D2 shows an antenna with filaments coupled in a fixed phase relationship. The objection of lack of inventive step above could also be based on a combination of D1 and D2.
6. Some of the drawings being common to the application and D1, claim 26 lacks novelty.

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**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

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International application No. PCT/GB00/03368

**Re Item VII**

Certain defects in the international application

1. Claim 26 contains a reference to the drawings. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here.
2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

**Re Item VIII**

Certain observations on the international application

The part of claim 1 specifying that "at least one filament group has a predetermined plurality of the filaments coupled together in a fixed phase relationship" is ambiguous and can be interpreted in different manners. "L" documents are cited in the search report to show different interpretations. An objection of lack of inventive step could be based on D1 combined with any of those documents.

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>4/W32338W0</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. <b>PCT/GB 00/ 03368</b>	International filing date (day/month/year) <b>01/09/2000</b>	(Earliest) Priority Date (day/month/year) <b>09/09/1999</b>
Applicant <b>UNIVERSITY OF SURREY</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

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☐ None of the figures.

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/03368

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01Q11/08 H01Q1/36 H01Q3/26

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 99 41803 A (SAUNDERS SIMON REZA ;UNIV SURREY (GB); AGIUS ANDREAS ALBERTOS (GB)) 19 August 1999 (1999-08-19) the whole document ----	1-26
Y	US 4 554 554 A (OLESEN RALPH C ET AL) 19 November 1985 (1985-11-19) the whole document ----	1-26
L	US 5 635 945 A (MCCONNELL RICHARD J ET AL) 3 June 1997 (1997-06-03) column 2, line 42 -column 4, line 19 ----	1-26
L	US 5 896 113 A (O'NEILL JR GREGORY A) 20 April 1999 (1999-04-20) column 5, line 24 - line 60 ----- -/--	1-26



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*G\* document member of the same patent family

Date of the actual completion of the international search

4 December 2000

Date of mailing of the international search report

18/12/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
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Authorized officer

Wattiaux, V

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/03368

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
L	US 5 920 292 A (O'NEILL JR GREGORY A) 6 July 1999 (1999-07-06) column 12, line 61 -column 17, line 33; figure 4 -----	1-26

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 00/03368

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9941803	A	19-08-1999	AU	2535899 A	30-08-1999
US 4554554	A	19-11-1985	NONE		
US 5635945	A	03-06-1997	NONE		
US 5896113	A	20-04-1999	AU	5899598 A	17-07-1998
			WO	9828816 A	02-07-1998
US 5920292	A	06-07-1999	AU	5699798 A	17-07-1998
			EP	0944931 A	29-09-1999
			WO	9828815 A	02-07-1998

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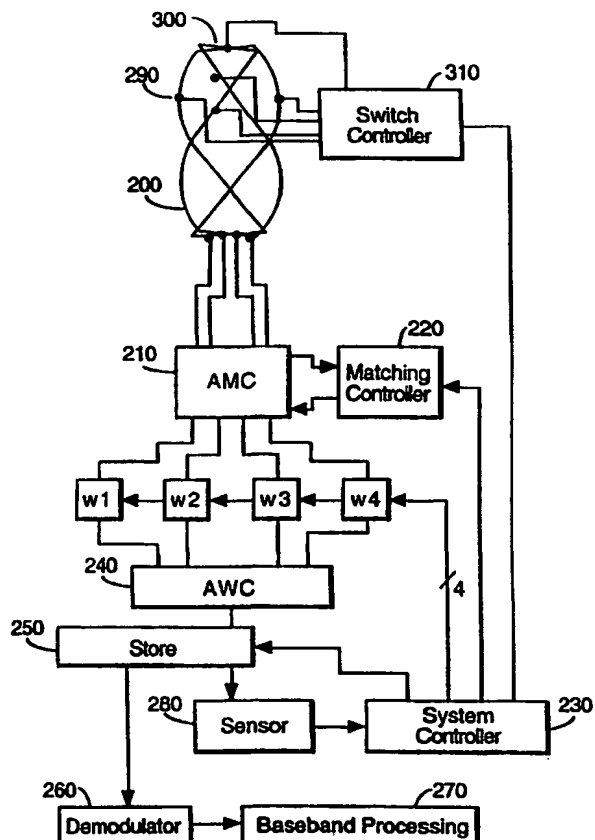
<b>(51) International Patent Classification <sup>6</sup> :</b> <b>H01Q 11/08, 5/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 99/41803</b>
		<b>(43) International Publication Date:</b> 19 August 1999 (19.08.99)

(74) **Agent:** MATHISEN, MACARA & CO.; The Coach House,  
6-8 Swakeleys Road, Ickenham, Uxbridge, Middlesex UB10  
8BZ (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

*With international search report.*

A multifilar antenna (200) comprises n spaced antenna filaments, where n is an integer greater than 1; a matching circuit (210) for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus; a weighting circuit (240) for applying respective gain and phase adjustments to signals passed to or from the n filaments; switch means (310) associated with each filament for selectively altering the electrical length and/or interconnections of the filaments; means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and control means (230), responsive to the detective means, for controlling the operation of the matching circuit (210), the weighting circuit (240) and the switch means (310) to adjust the properties of the multifilar antenna (200) to suit better a current signal to be received or transmitted.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
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## ADAPTIVE MULTIFILAR ANTENNA

This invention relates to adaptive multifilar antennas.

In fields such as mobile telephony and communication, it is being proposed that radio frequency transceivers operating in different frequency bands, and providing different services, should be integrated into single consumer devices.

For example, in order to improve the coverage area in which a mobile telephone can be used, a satellite system transceiver, a terrestrial transceiver and a domestic cordless telephone transceiver might be integrated into one hand-held unit. An alternative example is a dual service telephone operating at 1800MHz in the user's home country but having the capability of operating at 900MHz in other countries under a so-called roaming arrangement.

The electronics needed to achieve this aim are rapidly becoming smaller and lighter. A remaining problem area for multi-frequency, multi-system operation, however, is the antenna.

In order to operate as described above, an antenna should be able to work at different frequencies and with different types of base station. For example, one service may use terrestrial base stations and another may use orbiting satellites. This means that if the handset antenna is typically used in a vertical position (with the handset held next to the user's head) then for one service the antenna should have a radiation pattern substantially omnidirectional in azimuth and for the other service it should have an approximately hemispherical radiation pattern.

To cater for the different pattern and frequencies in use, it has been proposed to employ at least two distinct antennas within a common volume.

In a first aspect, the invention provides an adaptive multifilar antenna comprising:  $n$  spaced filaments, where  $n$  is an integer greater than 1;

a matching circuit for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus;

a weighting circuit operable to apply respective phase adjustments to signals passed to and/or from the  $n$  filaments;

detecting means operable to detect at least one electrical property of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and

control means, responsive to the detecting means, operable to control the operation of the weighting circuit to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

In another aspect, this invention also provides a multifilar antenna comprising:

$n$  spaced antenna filaments, where  $n$  is an integer greater than 1;

a matching circuit for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus;

a phasing circuit for applying respective gain and phase adjustments to signals passed to or from the  $n$  filaments;

switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments;

means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and

control means, responsive to the detecting means, for controlling the operation of the matching circuit, the phasing circuit and the switch means to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

In the invention, the phase and/or gain relationships for signals from individual

filaments of a multifilar antenna, along with the electrical length and interconnection pattern of the filaments, can be varied automatically in order to improve (or possibly to optimise, within the resolution of the adjustment system) the properties of the antenna for a particular signal to be received or transmitted.

For example, in embodiments of the invention, at least one of the above parameters could be varied to provide the best received signal level, the best signal to noise ratio, or the best signal to (noise plus interference) ratio and/or the best VSWR.

The adjustments will generally lead to a change in the antenna's frequency response and radiation pattern (shape and polarisation). It may not matter to the adjustment system what that change is quantitatively; the system may simply measure the output and make adjustments so as to improve the handling of the current signal.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a schematic diagram of a quadrifilar antenna;

Figure 2 is a schematic diagram of an antenna interface circuit;

Figure 3 is a more detailed schematic diagram of one possible implementation of the antenna system of Figure 2; and

Figure 4 is a more detailed schematic diagram of another possible implementation of the antenna system of Figure 2.

Figure 1 is a schematic diagram of a quadrifilar helical antenna (QHA).

The QHA comprises four helical elements 10..40 and eight radial elements 50..120. (In other embodiments six, for example, angularly spaced helical elements could be used).

The helical elements are intertwined as shown in Figure 1, and are disposed about a longitudinal axis of the antenna by 90° with respect to one another. Four of the radials

50..80 are disposed on the top and four 90..120 on the bottom of the volute, connecting the helical elements and forming two bifilar loops. The antenna is fed on one set of radials 90,110 with 90° phase difference between the two feeds.

The radials 50..80 at the top end of the antenna with respect to the feed (which in this example are at the bottom) may be shorted in pairs or may be open-circuit depending on the resonant length of the helical elements and the required response.

The QHA is described in the following references:

- [1] Kilgus C.C., "Multielement, Fractional Turn Helices", IEEE Transactions on Antenna and Propagation, Vol.AP-16, pp.499-500, July 1968
- [2] Kilgus C.C., "Resonant Quadrifilar Helix", IEEE Transactions on Antenna and Propagation, Vol.AP-17, pp. 349-351, May 1969
- [3] Kilgus C.C., "Resonant Quadrifilar Helix Design", The Microwave Journal, December 1970.

The antenna's radiation pattern mode (hemispherical or other) depends on the phase combination used on the two or four feeds. The exact shape of the antenna's radiation pattern in each mode depends on the pitch and dimensions of the helices. In the axial mode it has a shape varying from hemispherical to cardioid depending on the dimensions of the structure. The polarisation is circular with a very good axial ratio inside the 3dB angle.

In other embodiments, the multifilar antenna arrangement can also be used for diversity purposes. The different filaments can be used to provide space diversity between generally uncorrelated received signals. The effect of weighting the gain and/or phase can affect both the shape and the polarisation of the radiation pattern. This effect can benefit the transceiver in two ways. Firstly, the pattern shape and the polarisation are matching the direction and the polarisation of the incoming signal to try to optimise or improve the criterion ratio ( $S/N$  or  $S/(N+I)$ ), and secondly the structure can be used for

polarisation diversity using the resulting pattern of different filaments or pairs of filaments.

Figure 1 shows an antenna which has a generally cylindrical volute (i.e. circular in plan). Other volute shapes such as those having elliptical or rectangular plans are also suitable for use in the present invention.

Figure 2 is a schematic diagram of an antenna system comprising an adapted QHA 200 and an antenna interface circuit.

In Figure 2, the four elements of the QHA 200 are connected separately to an adaptive matching circuit 210. (In the configuration shown in Figure 2, the antenna is in a receive mode, but it will be clear that signals could instead be supplied to the antenna, in a transmit mode, by reversing the direction of signal propagation arrows in Figure 2.) The adaptive matching circuit 210 is under the control of a matching controller 220, which in turn is responsive to a system controller 230.

Received signals from the adaptive matching circuit are supplied to four respective variable weighting circuits W1..W4. Each of W1..W4 comprises a variable phase delay and optionally, a variable gain stage, all controllable by the system controller 230.

The outputs of the four variable weighting elements W1..W4 are combined by an adder/weight combiner 240 to form a composite signal. This composite signal is then stored 250. A sensor 280 examines the signal (e.g. the level of the signal to (noise plus interference) ratio) and passes this information to the controller which in turn adjusts the weighting factors of the weighting elements W1..W4, the matching circuit 210 and the switch elements 290,300 to improve or possibly optimise the parameter sensed by the sensor 280. The optimisation information can be used to optimise or improve the quality of the stored signal, which is then passed to the demodulator 260. The information is also used to adjust the antenna system to receive the next incoming signal.

In each element of the QHA, there is a switch 290 capable of isolating a portion

of the element remote from the feed point. The switch could be, for example, a PIN diode switch. Similarly, a switch 300 is capable of shorting or isolating pairs of the elements at the end remote from the feed point.

The operations performed by the switches 290 and 300, under the control of a switch controller 310, can change the response and radiation pattern of the antenna. In particular, by isolating a section of each element, the electrical length of the elements is made shorter and so the frequency of operation will be higher. Again, these operations are carried out under the control of the system controller to improve or possibly optimise operation with a particular signal frequency, polarisation and direction of propagation.

Alternatively, or additionally, the antenna element may be caused to have several resonant modes by the inclusion of one or more antenna traps. This causes the antenna to be resonant (and therefore have increased gain) at more than one operating frequency.

Figure 3 is a more detailed schematic diagram of one possible implementation of the antenna system of Figure 2, which also shows operation to improve or optimise the VSWR during a transmission operation and S/N+I during a receive mode. (Incidentally, when S/N+I is improved by adapting the antenna matching in a receive mode, this has an indirect side-effect of tending to improve the VSWR. Also, when the pattern mode, polarisation and direction are improved by adjusting for the best or an improved S/N+I, this similarly has a corresponding improving effect in a transmit mode.)

In Figure 3, the operation of the weighting elements W1..W4 is carried out at baseband in a digital domain, as is the operation of the adder/weight combiner 240.

The output of the adaptive matching circuit 210 is supplied to a quadrature downconverter 400 comprising an intermediate stage 410 where a local oscillator signal is mixed with the radio frequency signal, an amplifier 420 and a further stage of mixing with a local oscillator signal with a 0° and 90° phase relationship to generate two demodulated outputs I and Q. These are both converted to digital representations by A/D

converters 430 before being stored in a RAM 440. This process is replicated for each of the filaments of the QHA. Similarly, for the transmit side, an output from the RAM 440 is passed to a quadrature modulator 450 before being routed via the adaptive matching circuit 210 to the respective antenna filaments. A VSWR detector 460 operates in a transmit and/or receive mode to detect the standing wave ratio of the antennas. The output of this is stored in the RAM 440.

The RAM is connected to a digital signal processing (DSP) unit 470 which combines the digital representations of the signals stored in the RAM 440 in respective proportions and using respective phases (i.e. performs the operation of the weighting blocks W1..W4), detects and optimises the selected parameter such as signal-to-noise ratio, sends control signals to the adaptive matching circuits to change from one frequency band to another or to overcome de-tuning effects, and also controls the switch controller 310 and in turn the switches 290,300 within the helical elements.

One appropriate DSP algorithm is for the transmitter to send packet header, reference or training symbols, which are known to the receiver. Any disturbance to the received signals during the reception of the training symbols is a measure of N+I and can be reduced by trial and error (repeated combining of the digital representations stored in the RAM 440), direct matrix inversion of the associated correlation matrix or by iteration approaches such as so-called LMS or RLS algorithms. However, even if known training symbols are not available, a measure of the disturbance to the signal can be made by error detection algorithms applied to the received symbols.

Figure 4 is a more detailed schematic diagram of an alternative implementation of the antenna system of Figure 2. This implementation has a quadrature downconverter 400' which operates in the same way as the downconverter 400 of Figure 3. Similarly, it has a quadrature modulator 450' which operates in the same way as the modulator 450 of Figure 3.

The operation at baseband of the implementation shown in Figure 4 is also similar to that of Figure 3 in that the downconverted signals are converted into the digital domain and stored in a RAM 440'. The data in the RAM is processed by a digital signal processing unit 470' and the DSP 470' is operable to cause changes in the adaptive matching circuit 210' and in the antenna switches 290', 300' and 310'.

However, the operation of a circuit of Figure 4 differs significantly from that of Figure 3 in that the weighting operation is performed at RF in weighting blocks 500 which are coupled in the signal path from the individual antenna elements to the quadrature downconverter 400'.

In Figure 4, the weighting block 500 is coupled directly between the adaptive matching circuit 210' and a combiner 240' which operates to additively combine the outputs of the respective weighting circuits W1, W2, W3, W4 contained in the weighting block 500.

The output of the combiner 240' is fed into a single quadrature downconverter 400'. Thus, unlike the implementation shown in Figure 3, only one downconverter 400' is required. Similarly, only one quadrature modulator 450' is required.

This alternative implementation has two main advantages. Firstly, since only one downconverter 400' and one modulator 450' is required, there is a resultant cost saving in the manufacture of the transceiver.

Secondly, since most of the noise in the received signal is introduced by the receiver, there is a fourfold decrease in the noise added by the receiver section since the signal passes through only one (instead of four) downconverters 400'. As a further subsidiary advantage, since the signal from all four antenna elements is subjected to the same noise in the single downconverter 400', it is not necessary to apply gain weightings. Thus the weighting circuits W1, W2, W3, W4 may be arranged only to apply phase adjustments to the signals received by the antenna elements. This simplifies their



construction and therefore also has cost and reliability advantages.

In order to optimise the weightings, a slightly different approach may be taken to that used with the implementation of Figure 3. It will be noted that in the implementation of Figure 3, the stored data may be iteratively processed with different weightings applied to the data until an optimal or at least improved result is obtained. However, in the implementation of Figure 4, the data stored in the RAM 440' already has weightings applied to it and in fact the signals from each of the elements of the antenna have already been combined by the combiner 240'. Thus, in order to find the correct weightings, the weightings are adjusted dynamically during reception of a signal (for example a training sequence). By storing data representing the known weighting settings against data representing the quality of the received signal, it is possible to determine which weighting gives the best reception and/or transmission characteristics. Thus the principles are similar but in the first case (Figure 3) the weighting optimisation may occur "off line" whereas in the implementation of Figure 4, the weighting optimisation occurs "on line" during reception of a signal.

CLAIMS

1. An adaptive multifilar antenna comprising:
  - n spaced filaments, where n is an integer greater than 1;
  - a matching circuit for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus;
  - a weighting circuit operable to apply respective phase adjustments to signals passed to and/or from the n filaments;
  - detecting means operable to detect at least one electrical property of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and
  - control means, responsive to the detecting means, operable to control the operation of the weighting circuit to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.
2. An antenna according to claim 1, wherein the weighting circuit is operable to apply gain adjustments to signals passed to and/or from the n filaments.
3. An antenna according to claim 1 or claim 2, wherein the control means is operable to control the operation of the matching circuit to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.
4. An antenna according to any preceding claim, including switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments and the signal connections to/from the filaments being at a first end of

each filament; and

the switch means being operable to selectively interconnect pairs of filaments at a second end of those filaments remote from the first end.

5. An antenna according to any preceding claim, including switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments and

each filament including at least a first filament section and a second filament section; and

the switch means being operable to selectively connect or isolate the first and second filament sections of each filament so as to vary the electrical length of that filament.

6. An antenna according to any one of the preceding claims, in which:

the detecting means is operable to detect a signal to noise ratio of a received signal; and

the control means is operable to control the operation of the matching circuit and/or the weighting circuit so as to improve the signal to noise ratio of the received signal.

7. An antenna according to any one of the preceding claims, in which:

the detecting means is operable to detect a signal to (noise plus interference) ratio of a received signal; and

the control means is operable to control the operation of the matching circuit and/or the weighting circuit so as to improve the signal to (noise plus interference) ratio of the received signal.

8. An antenna according to any one of the preceding claims, in which:  
the detecting means is operable to detect a signal level of a received signal; and  
the control means is operable to control the operation of the matching circuit  
and/or the weighting circuit so as to improve the signal level of the received signal.
9. An antenna according to any one of the preceding claims, in which:  
the detecting means is operable to detect a VSWR for a transmitted signal; and  
the control means is operable to control the operation of the matching circuit  
and/or the weighting circuit so as to improve the VSWR for transmission of that signal.
10. An antenna according to any one of the preceding claims, in which the detecting  
means comprises:  
analogue to digital conversion means for converting respective signals received by  
the filaments into corresponding digital representations  
a memory for storing the digital representations;  
means for combining the digital representations using respective phase  
relationships and gains; and  
means for detecting properties of the antenna by analysis of the combined digital  
representations.
11. An antenna according to any one of claims 1 to 9, in which the detecting means  
comprises:  
means for combining respective signals received by the filaments using respective  
phase relationships  
analogue to digital conversion means for converting the combined signals into a  
corresponding digital representation;

a memory for storing the digital representation; and  
means for detecting properties of the antenna by analysis of the combined digital representations.

12. An antenna according to claim 11, wherein the combining means is operable to combine the respective signals using respective gain weightings.

13. An antenna according to any one of the preceding claims, in which the detecting means operates at least during reception of a reference signal burst by the antenna.

14. An antenna according to any one of the preceding claims, in which  $n$  is an even integer.

15. An antenna according to any one of the preceding claims, in which  $n$  is equal to 4 or 6.

16. An antenna according to any one of the preceding claims, in which the filaments are helically shaped.

17. An antenna according to any one of the preceding claims, in which the filaments are at least partially intertwined.

18. An antenna according to any preceding claim, having a volute of generally elliptical or rectangular axial cross-section.

19. An antenna according to any preceding claim, wherein the weighting circuit

operates at baseband.

20. An antenna according to any of claims 1 to 18, wherein the weighting circuit operates at RF.

21. An antenna according to claim 20, wherein the respective outputs of the weighting circuit are combined prior to frequency downconversion.

22. An adaptive multifilar antenna comprising:

n spaced antenna filaments, where n is an integer greater than 1;

a matching circuit for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus;

a phasing circuit for applying respective gain and phase adjustments to signals passed to or from the n filaments;

switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments;

means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and

control means, responsive to the detecting means, for controlling the operation of the matching circuit, the phasing circuit and the switch means to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

23. A multifilar antenna substantially as hereinbefore described with reference to the accompanying drawings.

Fig.1.

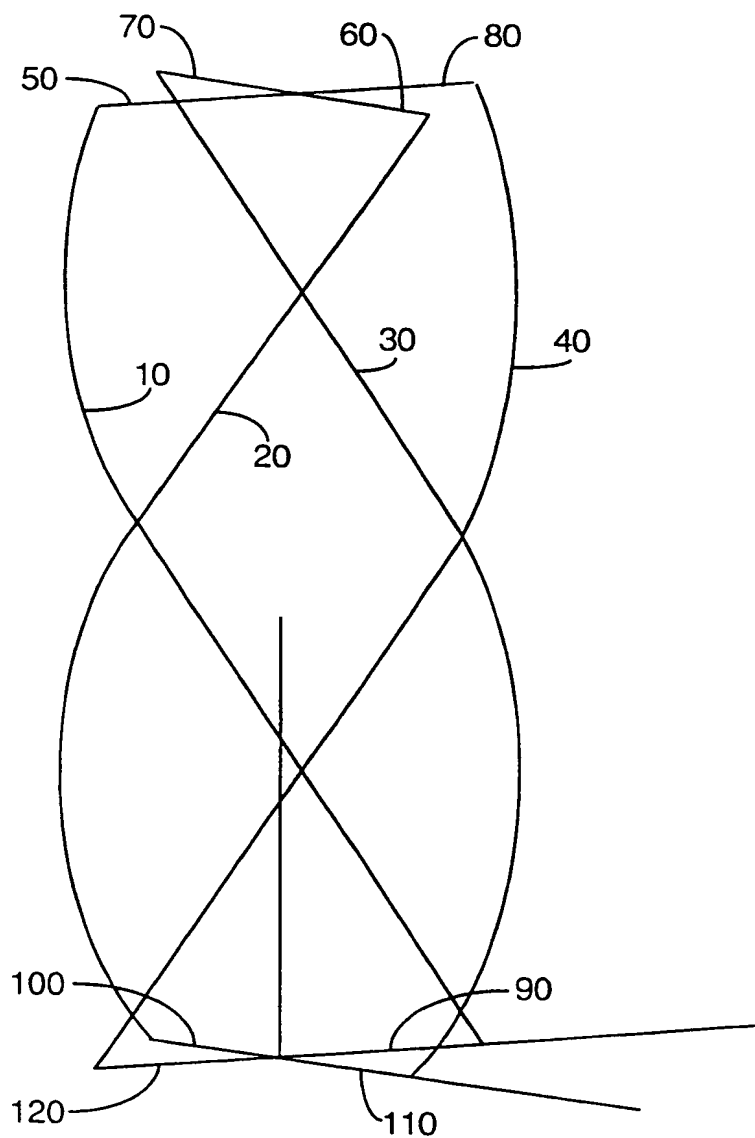
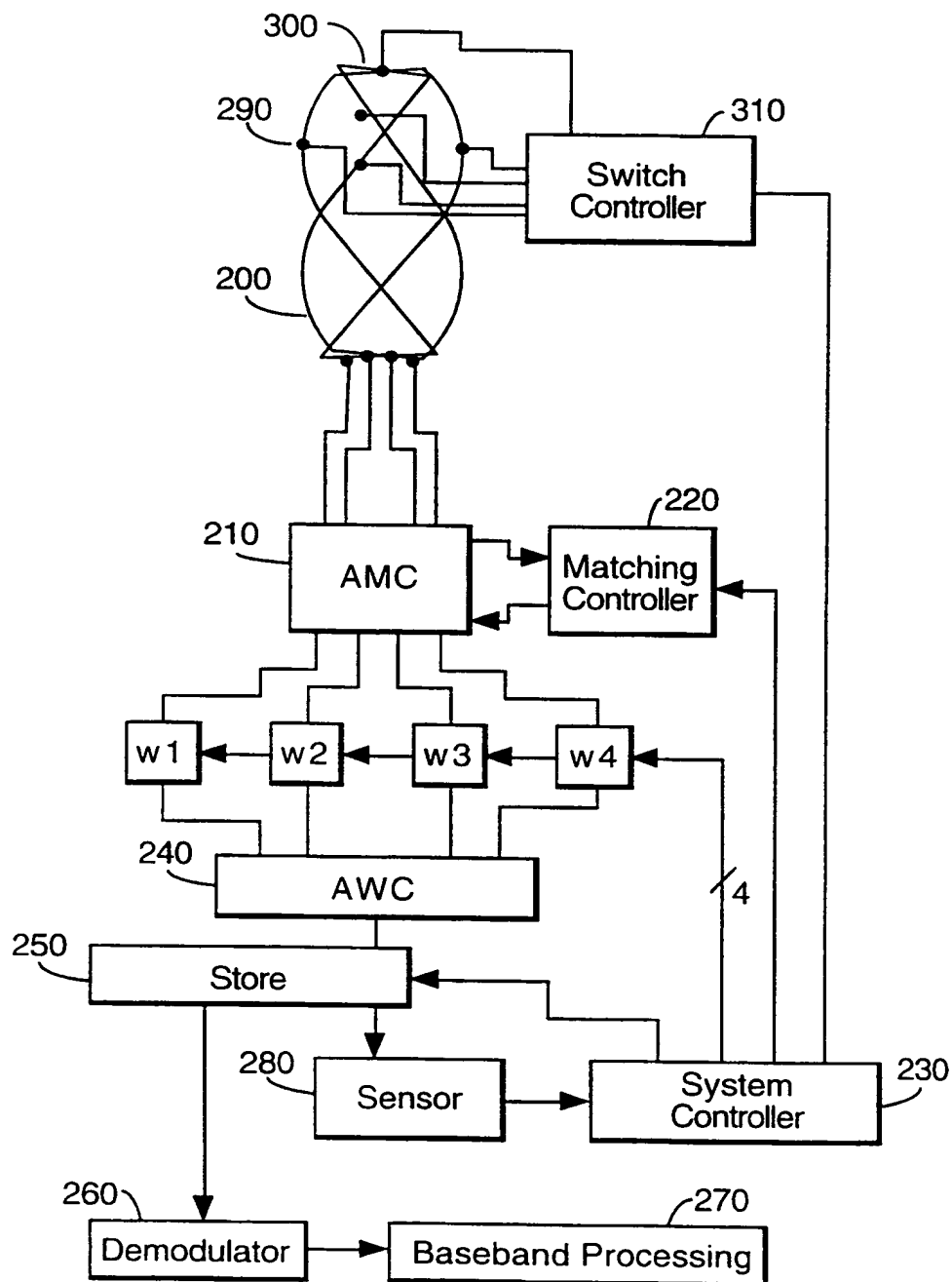
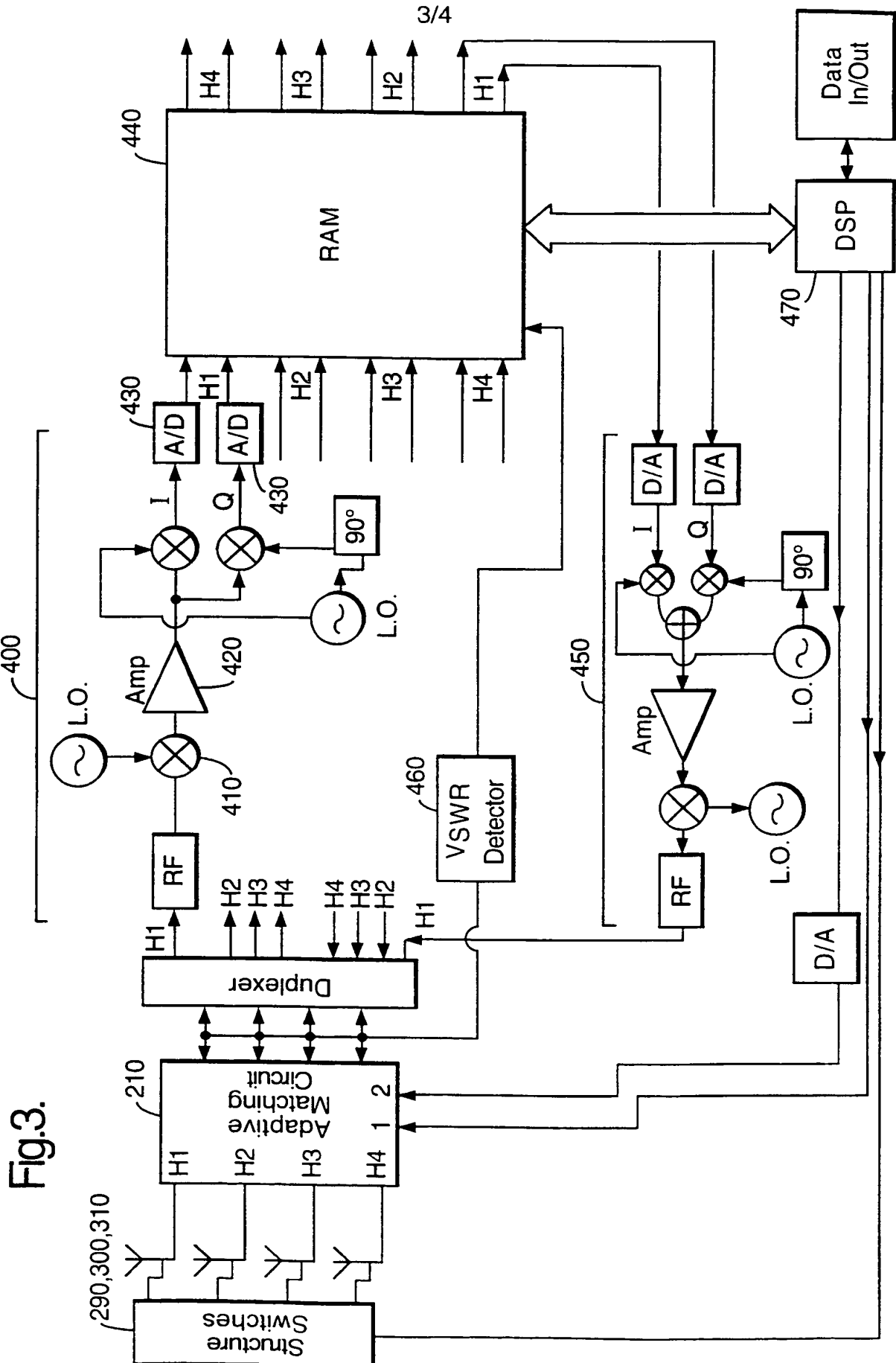
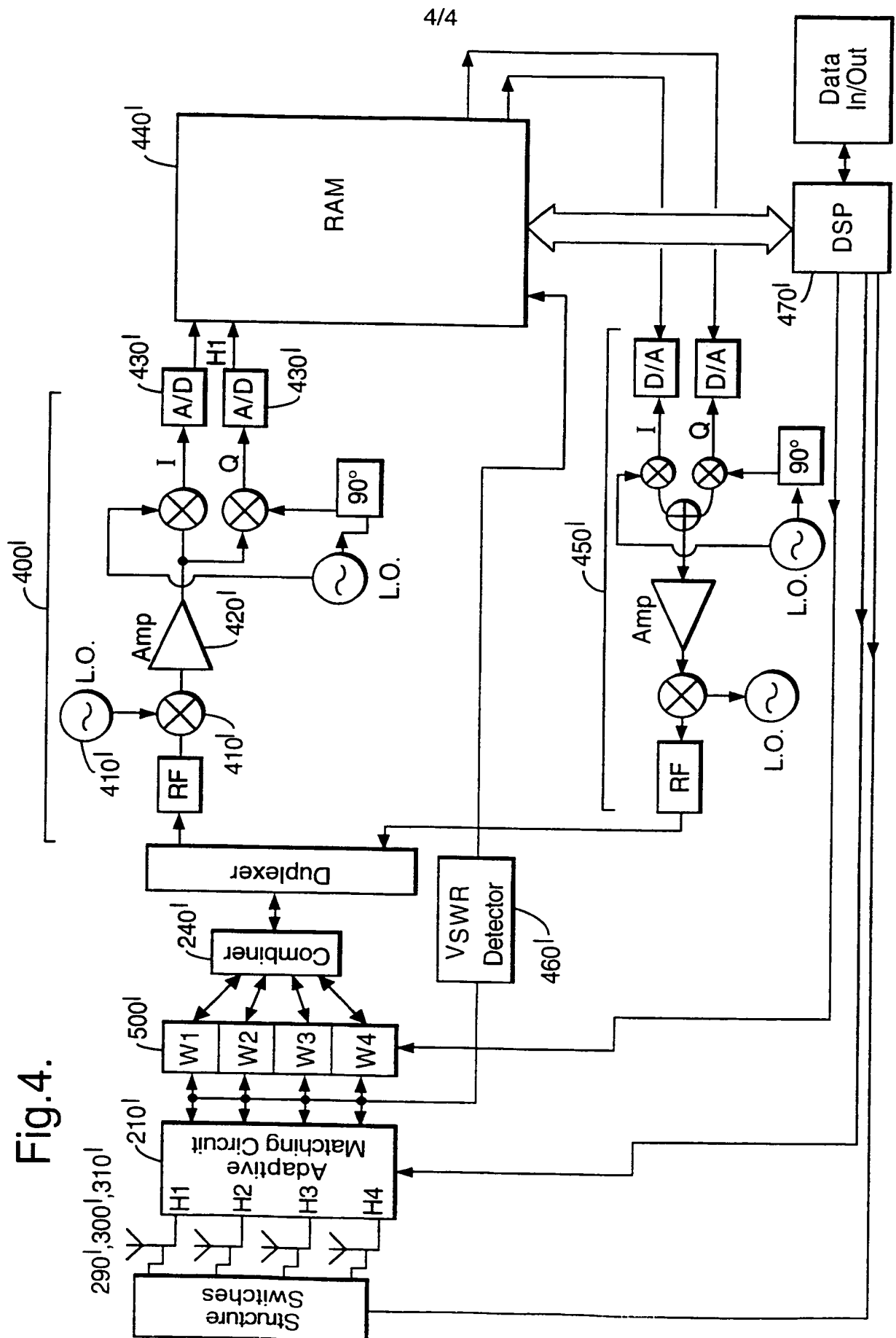


Fig.2.









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